Q.2a. Differentiate between the direct and indirect method of measurement.

Ans 2(a) There are two methods of measurement: 1) direct comparison with the standard, and 2) indirect comparison with the standard. Both the methods are discussed below:

1) Direct Comparison with the Standard

In the direct comparison method of measurement, we compare the quantity directly with the primary or secondary standard. Say for instance, if we have to measure the length of the bar, we will measure it with the help of the measuring tape or scale that acts as the secondary standard. Here we are comparing the quantity to be measured directly with the standard.

Even if you make the comparison directly with the secondary standard, it is not necessary for you to know the primary standard. The primary standards are the original standards made from certain standard values or formulas. The secondary standards are made from the primary standards, but most of the times we use secondary standards for comparison since it is not always feasible to use the primary standards from accuracy, reliability and cost point of view. There is no difference in the measured value of the quantity whether one is using the direct method by comparing with primary or secondary standard. The direct comparison method of measurement is not always accurate

2) Indirect Method of Measurement

There are number of quantities that cannot be measured directly by using some instrument. For instance we cannot measure the strain in the bar due to applied force directly. We may have to record the temperature and pressure in the deep depths of the ground or in some far off remote places. In such cases indirect methods of measurements are used.

The indirect method of measurements comprises of the system that senses, converts, and finally presents an analogues output in the form of a displacement or chart. This analogues output can be in various forms and often it is necessary to amplify it to read it accurately and make the accurate reading of the quantity to be measured. The majority of the transducers convert mechanical input into analogues electrical output for processing, though there are transducers that convert mechanical input into analogues mechanical output that is measured easily.

b.Define limiting errors. A 0-10A ammeter has an accuracy of 1.5% of full scale reading. The current indicated by the ammeter is 2.5 A. Calculate the limiting values of current and percentage limiting error.

$$\delta A = \pm 1.5 \text{ \% of full scale reading}$$
$$= \pm \frac{1.5}{100} \times 10$$
$$= \pm 0.15 \text{ A}$$

Hence the limiting values of current are,

$$I = 2.5 \pm 0.15 \text{ A} = 2.35 \text{ A}, 2.65 \text{ A}$$

The percentage limiting error is,

$$\% e = \frac{\delta A}{A_S} \times 100 = \frac{0.15}{2.5} \times 100$$
$$= 6 \%$$

Q.3a. An AC bridge shown in Fig 1, has the following parameters: (8)

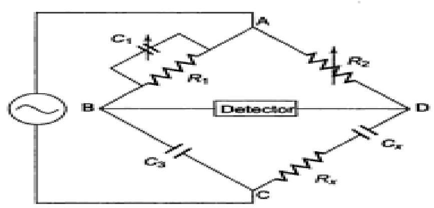

Fig.1

Arm AB- capacitor of 0.5μF in parallel with 1kΩ resistance
Arm AD- resistance of 2kΩ
Arm BC- capacitor of 0.5μF
Arm CD- unknown capacitor C_x and R_x in series
Frequency-1kHz
Determine the unknown capacitance and dissipation factor.

A 3a

$$R_x = \frac{C_1}{C_3} R_2 = \frac{0.5\,\mu F}{0.5\,\mu F} \times 2\text{ k} = 2\text{ k}\Omega$$

$$C_x = \frac{R_1}{R_2} \times C_3 = \frac{1\text{ k}}{2\text{ k}} \times 0.5\,\mu F = 0.25\,\mu F$$

The dissipation factor is given by

$$D = \omega C_x R_x$$
$$= 2 \times 3.142 \times 1000 \times 2\text{ k} \times 0.25\,\mu F$$
$$= 4 \times 3.142 \times 0.25$$
$$= 3.1416$$

b.Find the equivalent series resistance (Rx) and inductance (Lx) at balance for the given bridge as show in Fig. 2 **(8)**

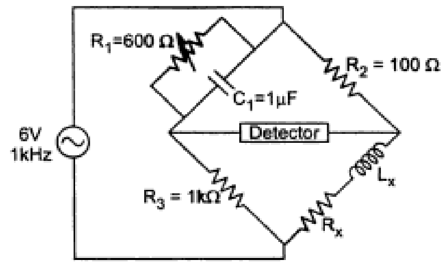

Fig.2

A.3b

$$\therefore \quad Y_1 = \frac{1}{R_1} + j\omega C_1$$

$$= \frac{1}{600} + j\left(2\pi \times 1000 \times 1 \times 10^{-6}\right)$$

$$= 1.66 \times 10^{-3} + j\,6.283 \times 10^{-3}$$

$$Z_2 = 100\,\Omega$$

$$Z_3 = 1000\,\Omega$$

$$Z_4 = R_x + j\,X_L = Z_x$$

From the basic balance equation,

$$Z_1 Z_4 = Z_2 Z_3$$

$$\therefore \quad Z_4 = \frac{Z_2 Z_3}{Z_1} = Z_2 Z_3 Y_1$$

$$= 100 \times 1000 \times [1.66 \times 10^{-3} + j\ 6.283 \times 10^{-3}]$$

$$= 166 + j\,628.3\,\Omega$$

$$= R_x + j\,X_L\,\Omega$$

$$\therefore \quad R_x = 166\,\Omega$$

$$\therefore \quad X_L = 628.3 = 2\pi f L_x$$

$$\therefore \quad L_x = \frac{628.3}{2\pi \times 1000}$$

$$= 0.099\ \text{H}$$

Q.4 a. Calculate the multiplier resistor required for a 100Vrms range on the voltmeter shown in given Fig 3. **(8)**

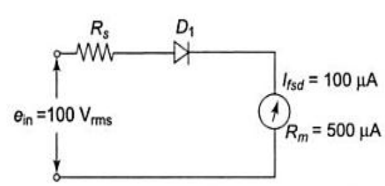

Fig.3

Method 1 Sensitivity of the voltmeter is given by

$$S_{dc} = 1/I_{fsd} = 1/100\ \mu A = 10^6/100 = 10\ k\Omega/V$$

$$R_s = S_{dc} \times \text{range} - R_m = 10\ k\Omega/V \times 0.45\ V \times 100 - 500\ \Omega$$
$$= 450\ k\Omega - 500\ \Omega = 449.5\ k\Omega$$

Method 2

$$R_s = \frac{0.45 \times E_{rms}}{I_{dc}} - R_m = \frac{0.45 \times 100}{100\ \mu A} - 500\ \Omega$$
$$= 0.45 \times 10^6 - 500\ \Omega$$
$$= 450\ k\Omega - 500\ \Omega = 449.5\Omega$$

b. Why a thermocouple is used in RF measurement of current?

Thermocouples instruments with heaters large enough to carry very large currents may have an excessive skin effect. Ordinary shunts cannot be used because the shunting ratio will be affected by the relative inductance and resistance, resulting in a frequency effect.

One solution to this problem consists of minimising the skin effect by employing a heater, which is a tube of large diameter, but with very thin walls.

Another consists of employing an array of shunts of identical resistance arranged symmetrically as shown in Fig. (a).

In Fig. (a) each filament of wire has the same inductance, so that the inductance causes the current to divide at high frequencies, in the same way as does the resistance at low frequencies. In Fig. (b) the condensor shunt is used such that the current divides between the two parallel capacitors proportional to their capacitance, and maintains this ratio independent of frequency, as long as the capacitor that is in series with the thermocouple has a higher impedance than the thermocouple heater and the lead inductance is inversely proportional to the capacitances.

In Fig. (c) the current transformer is used to measure very large RF currents at low and moderate frequencies using a thermocouple instrument of ordinary range. Such transformers generally use a magnetic dust core. The current ratio is given by

$$\frac{\text{Primary Current}}{\text{Secondary Current}} = \frac{1}{K}\sqrt{\frac{L_s}{L_p}}\sqrt{1+\frac{1}{Q_s}}$$

where L_s = secondary inductance
L_p = primary inductance

$Q_s = \omega L_s / r_s = Q$ of the secondary circuit taking into account meter resistance

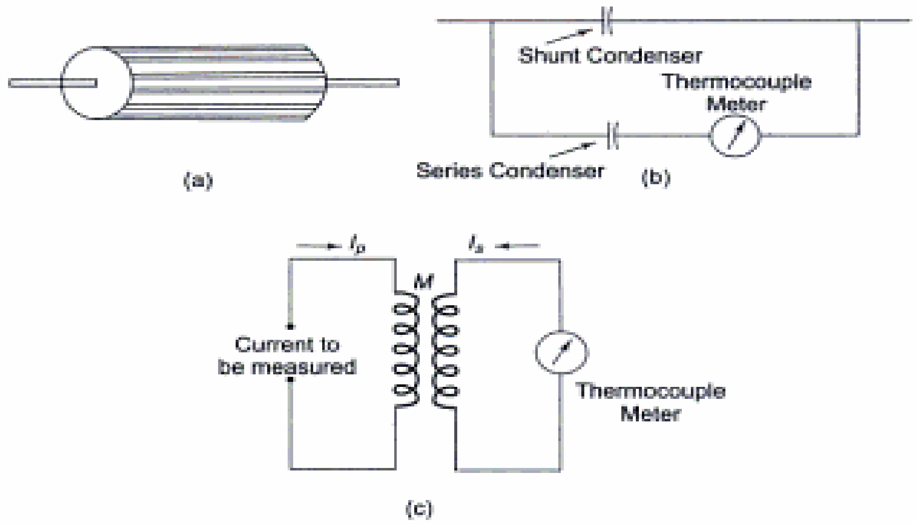

Fig. (a) Array of shunts (b) Condenser shunt (c) Current transformer

If Q of the secondary winding is appreciable (i.e. greater than 5), the transformation ratio is independent of frequency.

A current ratio of 1000 or more can be obtained at low and moderate RF by using a many turn secondary wound on a toroidal ring.

Q.5a. Explain with the help of a neat block diagram, the working of a digital frequency meter.

The assembly consisting of two F/Fs and two gates is called a gate control F/F. The block diagram of a digital frequency meter is shown in Fig.

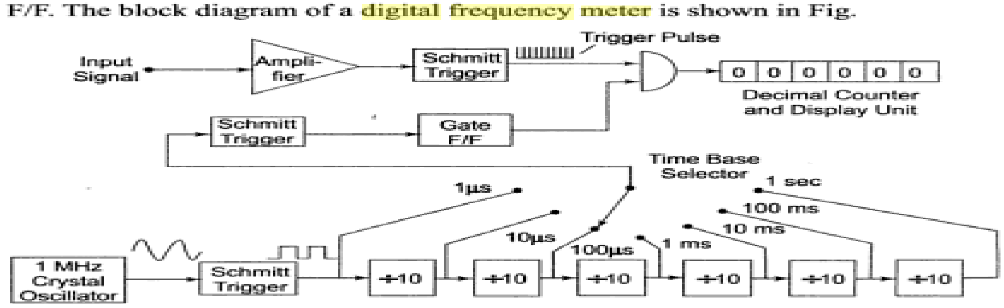

Fig. Block diagram of a digital frequency meter

The input signal is amplified and converted to a square wave by a Schmitt trigger circuit. In this diagram, the square wave is differentiated and clipped to produce a train of pulses, each pulse separated by the period of the input signal. The time base selector output is obtained from an oscillator and is similarly converted into positive pulses.

The first pulse activates the gate control F/F. This gate control F/F provides an enable signal to the AND gate. The trigger pulses of the input signal are allowed to pass through the gate for a selected time period and counted. The second pulse from the decade frequency divider changes the state of the control F/F and removes the enable signal from the AND gate, thereby closing it. The decimal counter and display unit output corresponds to the number of input pulses received during a precise time interval; hence the counter display corresponds to the frequency.

b. Explain with the help of a neat circuit diagram, the working of a dual slope DVM.

Principle of Dual Slope Type DVM As illustrated in Fig. , the input voltage 'e_i' is integrated, with the slope of the integrator output proportional to the test input voltage. After a fixed time, equal to t_1, the input voltage is disconnected and the integrator input is connected to a negative voltage $-e_r$. The integrator output will have a negative slope which is constant and proportional to the magnitude of the input voltage. The block diagram is given in Fig. .

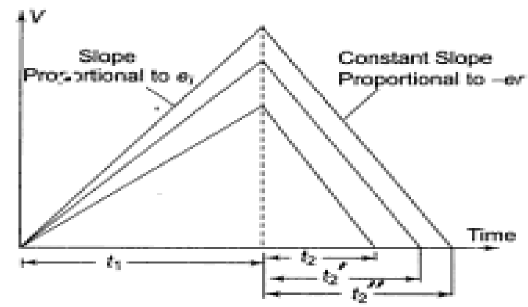

Fig. Basic principle of dual slope type DVM

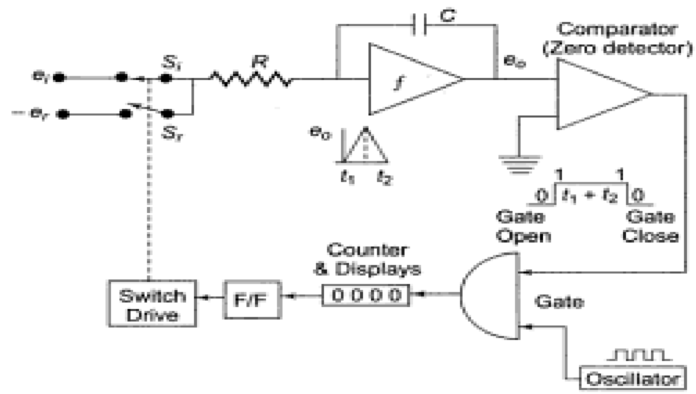

Fig. Block diagram of a dual slope type DVM

At the start a pulse resets the counter and the F/F output to logic level '0'. S_i is closed and S_r is open. The capacitor begins to charge. As soon as the integrator output exceeds zero, the comparator output voltage changes state, which opens the gate so that the oscillator clock pulses are fed to the counter. (When the ramp voltage starts, the comparator goes to state 1, the gate opens and clock pulse drives the counter.) When the counter reaches maximum count, i.e. the counter is made to run for a time 't_1' in this case 9999, on the next clock pulse all digits go to 0000 and the counter activates the F/F to logic level '1'. This activates the switch drive, e_i is disconnected and $-e_r$ is connected to the integrator. The integrator output will have a negative slope which is constant, i.e. integrator output now decreases linearly to 0 volts. Comparator output state changes again and locks the gate. The discharge time t_2 is now proportional to the input voltage. The counter indicates the count during time t_2. When the negative slope of the integrator reaches zero, the comparator switches to state 0 and the gate closes,

Q.6 a. Draw the block diagram of a function generator and explain the method of producing sine waves.

A6

A function generator produces different waveforms of adjustable frequency. The common output waveforms are the sine, square, triangular and sawtooth waves. The frequency may be adjusted, from a fraction of a Hertz to several hundred kHz.

The various outputs of the generator can be made available at the same time. For example, the generator can provide a square wave to test the linearity of an amplifier and simultaneously provide a sawtooth to drive the horizontal deflection amplifier of the CRO to provide a visual display.

Capability of Phase Lock The function generator can be phase locked to an external source. One function generator can be used to lock a second function generator, and the two output signals can be displaced in phase by adjustable amount.

In addition, the fundamental frequency of one generator can be phase locked to a harmonic of another generator, by adjusting the amplitude and phase of the harmonic, almost any waveform can be generated by addition.

The function generator can also be phase locked to a frequency standard and all its output waveforms will then have the same accuracy and stability as the standard source.

The block diagram of a function generator is illustrated in Fig. Usually the frequency is controlled by varying the capacitor in the LC or RC circuit. In this instrument the frequency is controlled by varying the magnitude of current which drives the integrator. The instrument produces sine, triangular and square waves with a frequency range of 0.01 Hz to 100 kHz.

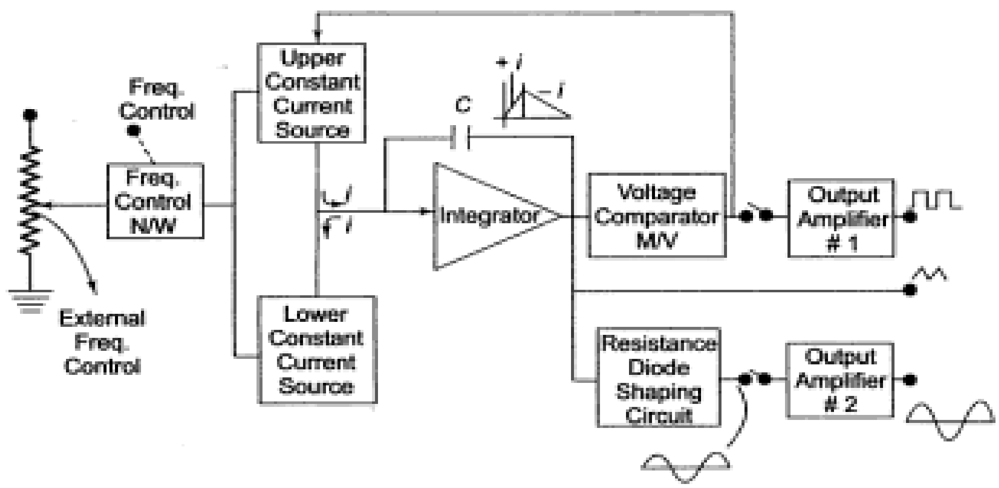

Fig. Function generator

b.Draw the basic block diagram of an oscilloscope and explain the function of each block.

The frequency controlled voltage regulates two current sources. The upper current source supplies constant current to the integrator whose output voltage increases linearly with time, according to the equation of the output signal voltage.

$$e_{out} = -\frac{1}{C}\int_0^t i\,dt$$

An increase or decrease in the current increases or decreases the slope of the output voltage and hence controls the frequency.

The voltage comparator multivibrator changes states at a pre-determined maximum level of the integrator output voltage. This change cuts off the upper current supply and switches on the lower current supply.

The lower current source supplies a reverse current to the integrator, so that its output decreases linearly with time. When the output reaches a pre-determined minimum level, the voltage comparator again changes state and switches on the upper current source.

The output of the integrator is a triangular waveform whose frequency is determined by the magnitude of the current supplied by the constant current sources.

The comparator output delivers a square wave voltage of the same frequency. The resistance diode network alters the slope of the triangular wave as its amplitude changes and produces a sine wave with less than 1% distortion.

Q.7 a. Explain an arrangement for the measurement of a standing wave ratio.

Standing waves are created along the length of a transmission line due to the mismatch between the characteristic impedance Z_o and the terminating impedance of the transmission line.

The actual voltage E on the line at any point is the sum $(E_i + E_r)$ of the voltage of the incident and reflected waves at the point. This results in a voltage distribution on the line, such as illustrated in Fig. called a standing wave pattern.

If on a certain line there is both an incident and a reflected wave, a voltage maxima occurs at points where the two waves are in the same phase, and a minima at points where the two waves are in phase opposition.

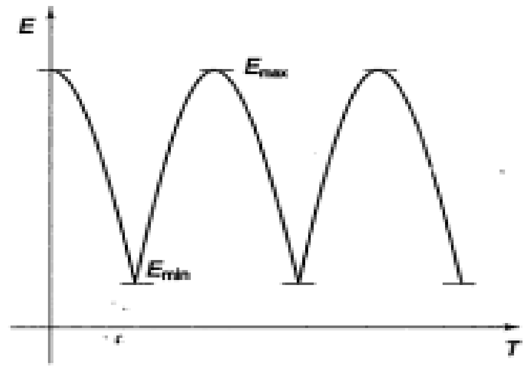

Fig. Standing wave pattern

When the difference between maxima and minima is more pronounced, the larger the reflection coefficient. In particular, when the reflection coefficient of the load is unity, the minima are very deep, while when the reflection coefficient of the load is zero, there is no standing wave pattern.

The distance between adjacent minima (or maxima) is exactly half the line wavelength.

The ratio of the maximum to the minimum value of voltages (or currents) in the standing wave pattern is termed the standing wave ratio.

Voltage standing wave ratio

$$S = \frac{E_{max}}{E_{min}} = \frac{|E_i| + |E_r|}{|E_i| - |E_r|}$$

where $E_{max} = |E_i| + |E_r|$
$E_{min} = |E_i| - |E_r|$

If the line has no attenuation, the standing wave ratio, S, is the same everywhere. (If the line has losses, S decreases with increasing distance from the load.)

If directional couplers are used for measurement of the standing wave ratio, then V_2 indicates $|E_i|$, V_1 indicates $|E_r|$ and the standing wave ratio is

$$S = \frac{(V_1 + V_2)}{(V_1 - V_2)}$$

b. Explain with the help of block diagram, the working of a harmonic distortion analyzer.

Heterodyne Harmonic Distortion Analyzer

In this type of analyzer, a highly selective, fixed frequency filter is used. The Fig. shows the functional block diagram of heterodyne type harmonic distortion analyzer.

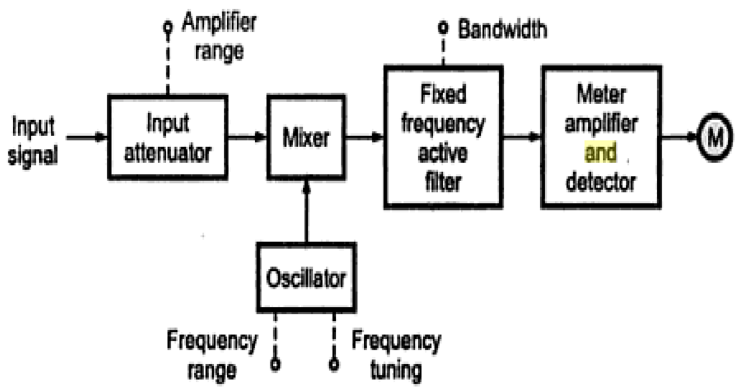

Fig. Heterodyne harmonic distortion analyzer

The variable frequency oscillator output is mixed with each harmonic of the input signal, with the help of balanced mixer, either the sum or difference frequency is made equal to the frequency of the filter. The quartz crystal type highly selective filters can be used as each harmonic frequency is converted to a constant frequency. This allows to select constant frequency signal related to a particular harmonic and pass it to the metering circuit.

The balanced mixer consists of a balanced modulator and it eliminates original frequency of the harmonic. Generation of low harmonic distortion is the advantage of the balanced modulator. In some cases, the meter reading is calibrated directly interms of voltage while in some cases the harmonics are compared with a reference voltage, which is representation of the fundamental component. As the calibration interms of voltage is the feature of direct reading heterodyne harmonic distortion analyzer, they are also called **frequency selective voltmeters.** These instruments are also called **carrier frequency voltmeters** and **selective level voltmeters.**

Q.8 a. Compare X-Y recorders with strip chart recorders.

Comparison between X-Y Recorder and Strip Chart Recorder

	X-Y Recorder	Strip Chart Recorder
Principle of operation	This records one variable as a function of other variable. Two signals are connected to two inputs X and Y and then these are attenuated. The attenuated signals are compared with reference by the balance detectors separately and accordingly error signals are produced. These error signals are used to drive motors in X-direction and Y-direction.	The roll of chart paper moves at constant speed and the stylus with pen assembly moves along the chart in accordance with the input signal, varying with respect to time.
Dependent and independent variables	This recorder plots one input variable as a function of another input variable.	This recorder plots variation of input variable as a function of time as independent variable.
Recording mechanism	The error signal is converted to a.c. signal and then it is connected to servoamplifier. This servoamplifier drives servomotors. Out of two servomotors, one controls position of roll while other controls position of pen.	The position of the stylus is controlled by using potentiometer system.
Movement of chart paper	The chart paper is held stationary in X-Y recorder	The roll of chart paper is kept moving continuously at a constant speed.
Zero-offset adjustment	In modern X-Y recorder, zero offset adjustment is possible.	In strip chart recorder, zero offset adjustment is not possible.
Application	It is used to obtain speed torque characteristic of motors regulation characteristics of power supplies, to plot strain stress curves, hysteresis curve to plot characteristics of diodes, transistors etc.	It is used to record any physical quantity measured by the transducer.

b.Explain the working of a circular chart recorder.

CIRCULAR CHART RECORDER

As the name implies, the data is recorded on a flat circular chart. The basic assembly of a single pen circular chart recorder is shown in Fig.

It consists of a measuring element, an operating mechanism, a chart drive, and a recording device, which may all be mounted on a single panel. The chart is usually mounted on a flat supporting plate and fastened in position by spring clips, which prevent it from curling. The measuring element could be a helical pressure tube or any other element. The operating mechanism consists of levers a and b and links c which convey motion from the measuring element to the recording device.

Q.9 a. Draw and describe the following for thermistors:
(i) Resistance-temperature characteristics
(ii) Voltage-current characteristics
(iii) Current time characteristics

A9(a) (i)

The electrical resistance of most materials changes with temperature. By selecting materials that are very temperature sensitive, devices that are useful in temperature control circuits and for temperature measurements can be made.

Thermistor (THERMally sensitive resISTOR) are non-metallic resistors (semiconductor material), made by sintering mixtures of metallic oxides such as manganese, nickel, cobalt, copper and uranium.

Thermistors have a Negative Temperature Coefficient (NTC), i.e. resistance decreases as temperature rises. Figure shows a graph of resistance vs temperature for a thermistor. The resistance at room temperature (25°C) for typical commercial units ranges from 100 Ω to 10 MΩ. They are suitable for use only up to about 800°C. In some cases, the resistance of thermistors at room temperature may decrease by 5% for each 1°C rise in temperature. This high sensitivity to temperature changes makes the thermistor extremely useful for precision temperature measurements, control and compensation.

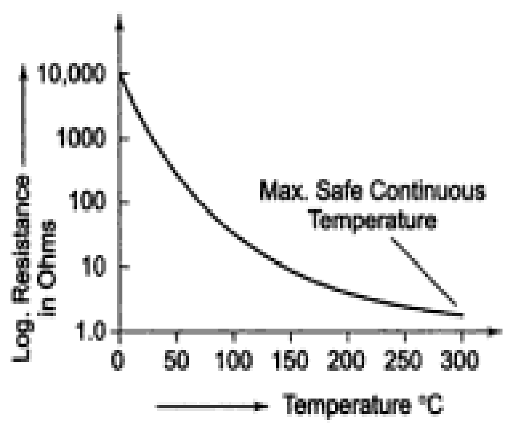

Fig. Resistance vs Temperature Graph of a Thermistor

(ii) & (iii)

Voltage Current Characteristics

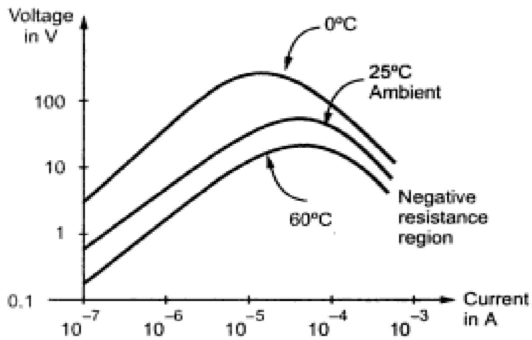

Fig. Voltage current characteristics

The voltage current characteristics of thermistor are shown in the Fig.

It can be seen that as current increases, the voltage across thermistor increases, attains a peak value and then decreases, when it decreases, the **negative resistance** region starts.

When small voltage is applied to thermistor, small current flows. This does not produce heat so as to change resistance of thermistor. Under this condition, it follows Ohm's law and V and I are proportional. But large currents produce large heat. This increases temperature to such a value where resistance of thermistor decreases and draws more current. The current continues to increase till heat dissipation of thermistor equals the power supplied to it. This is called **self heat** characteristics of thermistor. This makes it suitable to measure flow, pressure, liquid level etc. If rate of heat removal is fixed then thermistor is sensitive to power input and used for voltage or power level control.

Current Time Characteristics

At low voltages, the thermistor takes long time to reach peak current. As voltage level increases, the time to reach peak current decreases. These characteristics are called current time characteristics and are shown in the Fig.

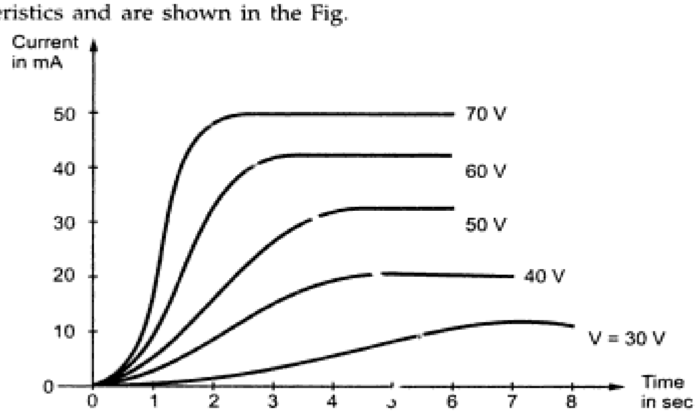

Fig. Current time characteristics

b. Explain D/A and A/D converters w.r.t. signal conditioning of the inputs.

Objectives of Data Acquisition System

i) The data acquisition system must acquire the necessary data at correct speed and at the correct time.

ii) It must use all the data efficiently to inform the operator about the state of the plant.

iii) It must monitor the operation of complete plant so that optimum online safe operations are maintained.

iv) It must provide effective human communication system which helps in identifying the problem areas. This minimises unit availability and maximises the unit output at lower cost.

v) It must be able to collect, summarise and store data properly for diagnosis and record purpose of any operation.

vi) It must be able to compute unit performance indices using online real time communication.

vii) It must be flexible. Also the expansion facility for the future requirement must be provided by it.

viii) It must be reliable and should not have a down time greater than 0.1%.

The data acquisition systems are basically used to measure and record the signals obtained in two ways. Firstly the signal may be originating from direct measurement of an electrical quantity such as a.c. or d.c. voltage, frequency, component value such as resistance, capacitance etc. Such signals are always found in electronic component testing, environmental studies etc. Secondly the signal may originate from the transducers such as pressure transducers, thermocouples.

Textbook

1. **A Course in Electrical and Electronic Measurements and Instrumentation, A.K Sawhney, Dhanpat Rai & Co,New Delhi, 19th Revised Edition 2011(Reprint 2012)**

2. **Electronic Instrumentation, H.S Kalsi, Tata McGraw Hill, 3rd Edition (fourth reprint 2012)**